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APOLLO RELIABILITY PROGRAM PLAN (U)

NAS9-150

Reissued 27 Dec 1963 Revised 29 May 1964

Exhibit I, Paragraph 3.8

Prepared by

Apollo Reliability

[redacted]

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NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

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INTRODUCTION

Apollo reliability activities are designed to emphasize preventive rather than curative measures to achieve the extreme, man-rated reliability and safety objectives. To this end, the preventive elements of the program concentrate on high-integrity design, stringent control measures, comprehensive ground testing, and personnel selection, assignment, training, and motivation. The following curative measures will be employed to supplement the foregoing:

1. Corrective actions resulting from analyses and reviews of designs, processes, and controls.

2. Rapid-response failure and problem reporting which emphasizes corrective measures and evaluation of the effectiveness of such action.

3. Continuous program reviews and reorientation to establish new priorities and rapidly resolve current problems.

Each of these program elements is defined further in subsequent sections of this report.

This report is reviewed and periodically revised as required to reflect program orientation and content. It is in loose-leaf form to enable individual pages to be changed, as required, rather than necessitate revision of the entire report. Changes will be identified by revision bars placed in the margin where the revision occurs and revised pages will contain revision dates. Revised pages will be listed at the front of the volume. Where applicable, existing reports, procedures, and specifications are referenced in this document rather than being duplicated herein. Such detailed information is available through S&ID and will be supplied upon request.

This document defines the detailed requirements for the Apollo reliability program, within the scope of NAA contractual obligations. Deviations from applicable documents previously referenced, are delineated in Appendix H and will take precedence over the originally stated requirements.

I. RELIABILITY POLICY AND ORGANIZATION

This section describes the S&ID reliability policy and organization, with emphasis placed on the applicability to the Apollo program. Organization charts are included to illustrate the functional relationships that exist between primary and supporting groups within the project.

RELIABILITY POLICY

Tightly integrated into Apollo development objectives and plans is the realization on the part of S&ID of the need for rapid and economical reliability growth and attainment of the maximum possible probabilities of success and crew survival. Management organizations and actions are directed toward this end. Resources and capabilities of the entire NAA corporate structure are available to assure program success.

The ambitious nature of the Apollo mission dictates that all management, functional, and support personnel recognize quality and reliability as parameters of equal or greater importance than cost, schedule, and performance. A centralized reliability program is fundamentally an aid to these individuals. It is not a substitute for dedication, thoughtfulness, care, and highly professional attitudes in performing assigned tasks, nor does it relieve any individual from his responsibilities toward ensuring that the spacecraft and support equipment are of high integrity, and, ultimately, that Apollo missions are successful.

MANAGEMENT AND ORGANIZATION

First-line responsibility for product integrity and quality rests with the division and Apollo program management. Apollo Reliability Engineering is delegated the responsibility for implementing a reliability program which will enhance achievement of reliability objectives. Reliability policy and guidance are provided by the Division President, Apollo Vice President and Program Manager, and Director of Test and Quality Assurance. (See Figure 1-1.)

Apollo Division

The Apollo Vice President and Program Manager is responsible to NASA and the Division President for the conduct of the program and for all

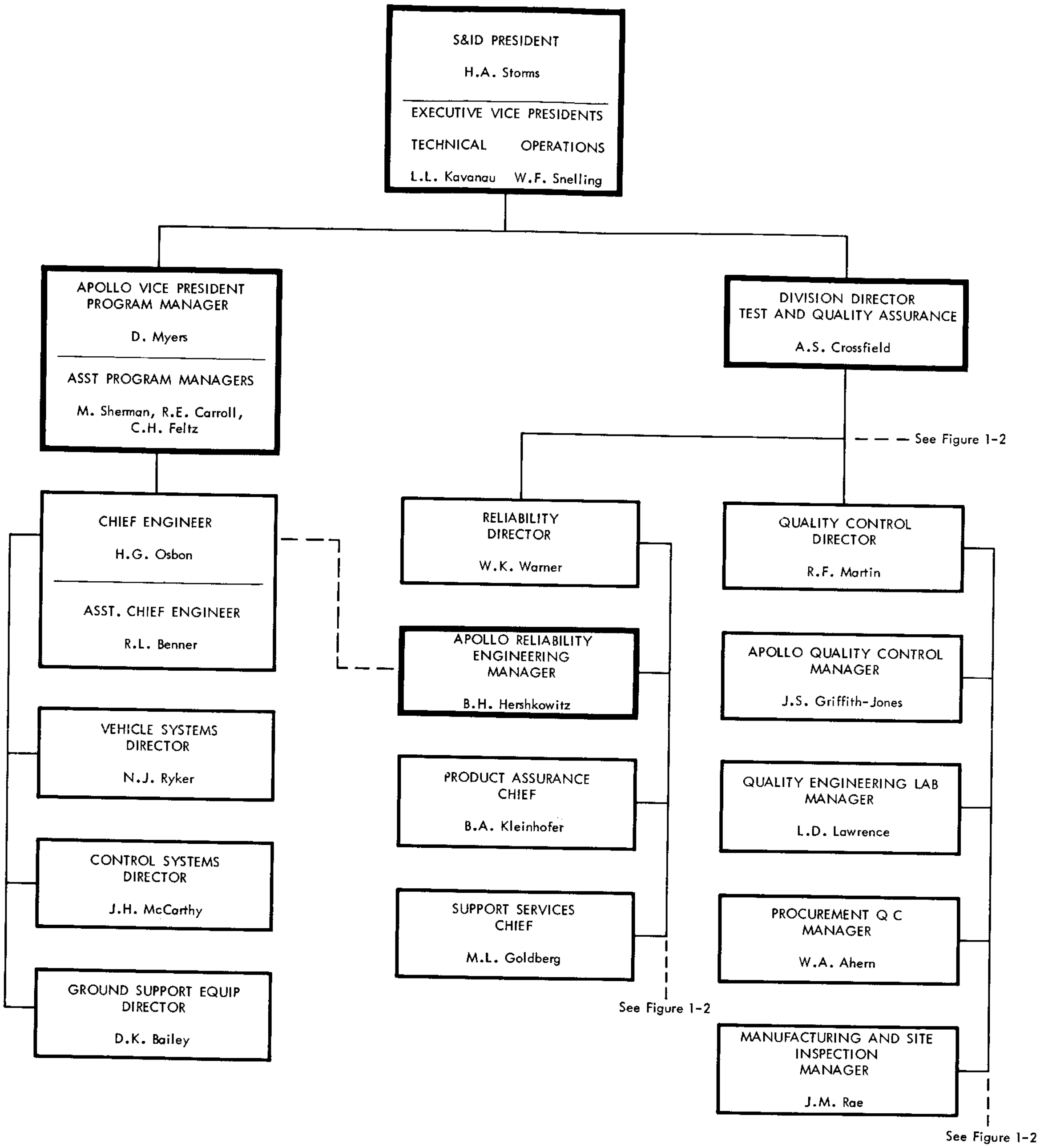

Figure 1-1. Apollo Reliability Organizational Responsibilities

its administrative and technical aspects. He is supported by a well-integrated organization representing the following functions:

Customer representatives
Associate contractor representatives
Program Control (S&ID, subcontractors, and suppliers)
Space Sciences
System Analysis
Subsystem Project Management
Material
Facilities
Logistics
Contracts
Engineering
Manufacturing
Administration
Test and Operations

Test and Quality Assurance

The Director of Test and Quality Assurance is responsible for the administration and conduct of S&ID Reliability and Quality activities. Within the framework of NASA and NAA corporate policies and requirements, he establishes Divisional reliability and quality policy and the organizations required to implement them. As illustrated in Figure 1-2, the Director of Test and Quality Assurance, and the organizations under him, advise, coordinate, and provide direct project support in the following fields:

Operations support
Data
Quality standards, engineering and control
Reliability analyses and reviews
Qualification tests
Statistics
Component application and evaluation
Training and certification

Apollo Reliability Manager

The Apollo Reliability Manager reports to the Director of Reliability Engineering and is in close technical contact with the Apollo Chief Engineer. The following are the responsibilities of the Reliability Manager:

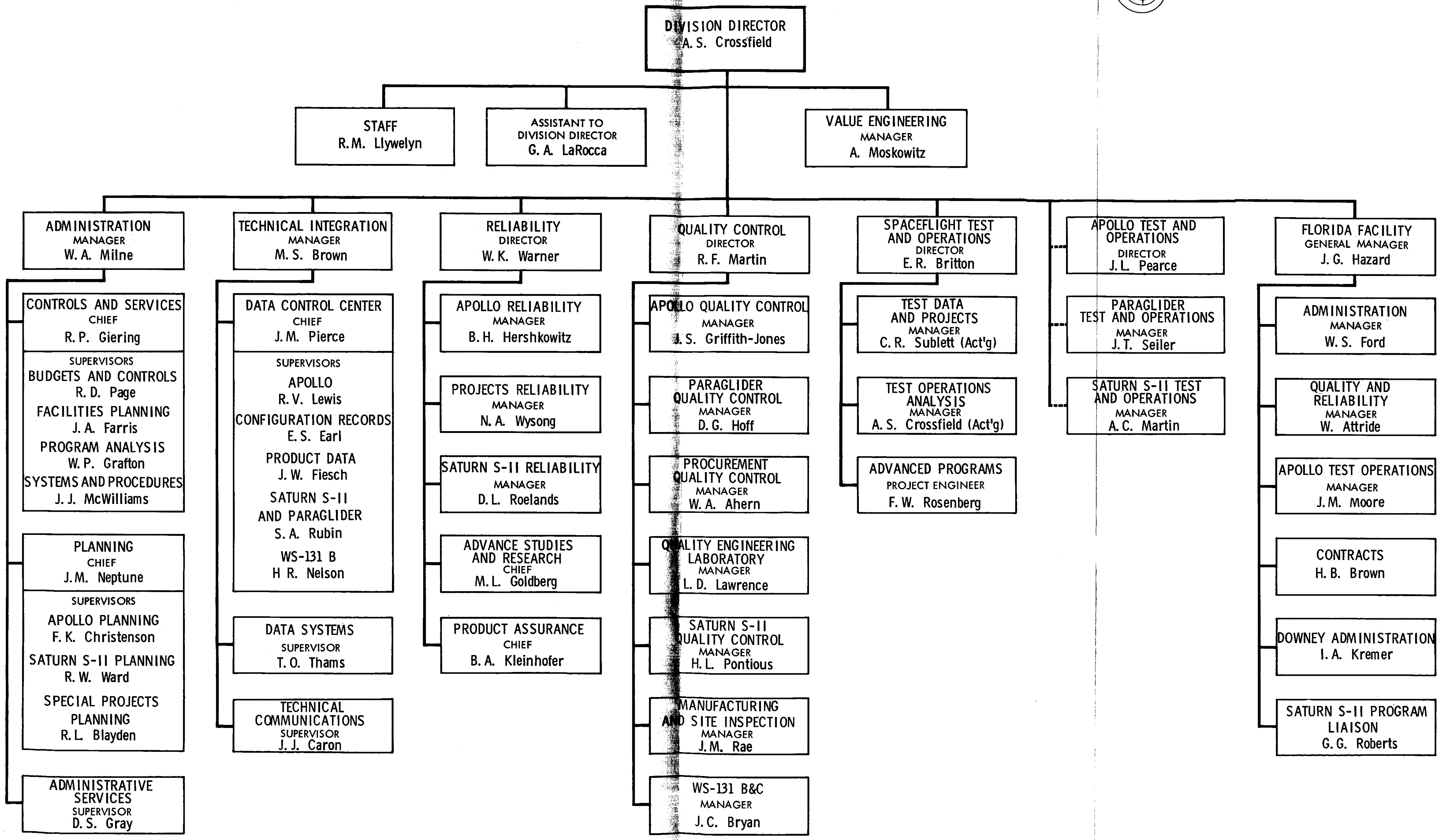

Figure 1-2. Test and Quality Assurance Organization

1-4.1,1-4.2

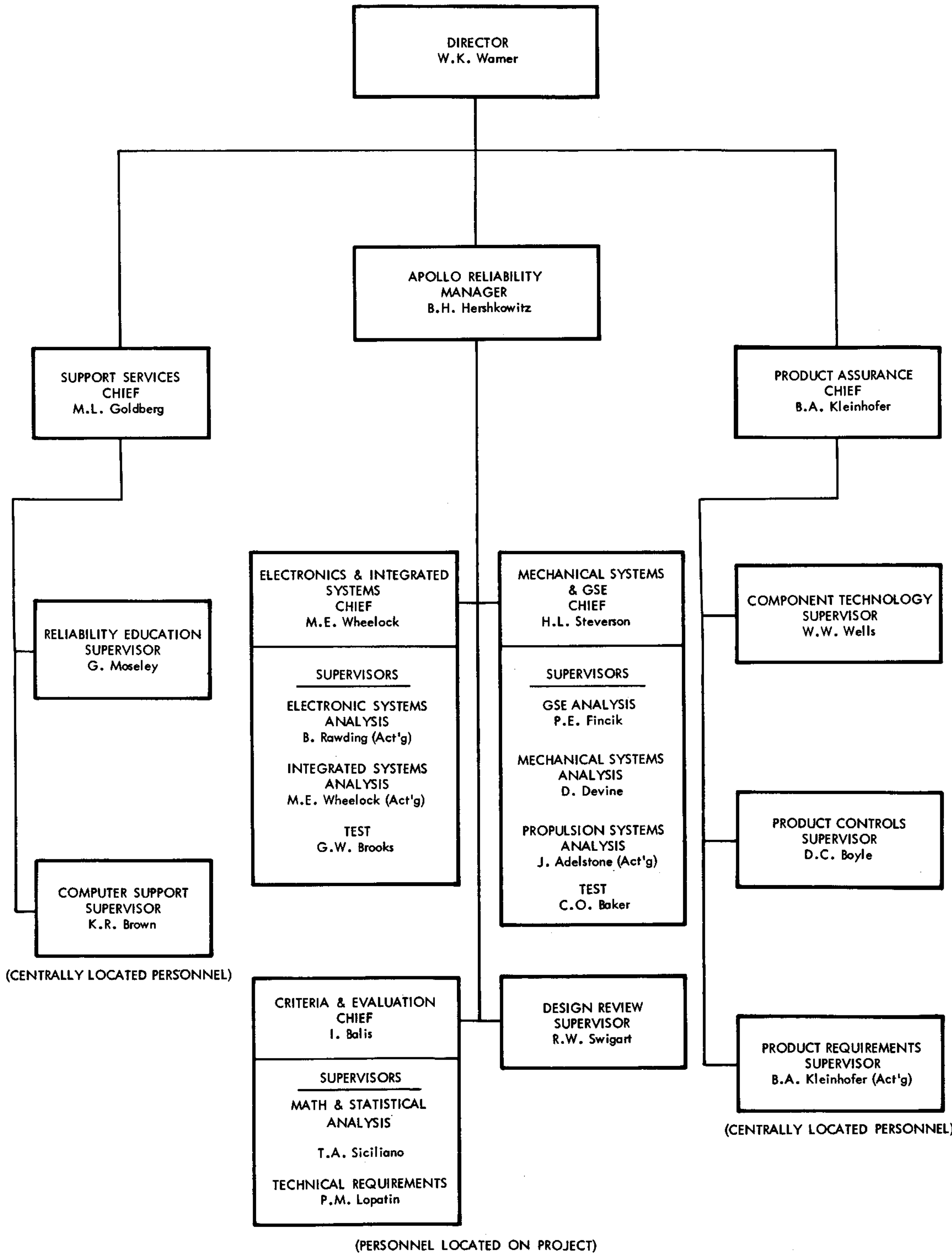

Figure 1-3. Reliability Engineering Organization

RELIABILITY
DIRECTOR
W. K. Warner

APOLLO RELIABILITY
MANAGER
B. H. Hershkowitz

PRODUCT ASSURANCE
CHIEF
B. A. Kleinhofer

COMPONENT TECHNOLOGY

Provides reliability and application data on parts for NAA and Subcontractor designs.
Maintains preferred parts and components lists.
Documents and maintains specifications and SCD's on common usage parts.
Conducts test programs to evaluate and improve reliability of common usage parts.

PRODUCT REQUIREMENTS

Determine contamination control criteria and requirements, product technical requirements for preferred processes, techniques and controls and provide specifications governing these areas.
Establish technical requirements for certification of personnel in areas of handling, test and installation of preferred parts, component and associated processes.
As directed, support design review by documenting potential problem areas and recommending changes.

PRODUCT CONTROLS

Specify and survey product processes and controls to assure that reliability is achieved in manufactured preferred parts and components and to prevent degradation throughout the testing, handling, storage, installation and estimated life span of preferred parts and components.

SUPPORT SERVICES
CHIEF
M. L. Goldberg

RELIABILITY EDUCATION

Provides reliability education for employees whose work influences reliability, through courses of instruction, publications, closed circuit TV, seminars and symposiums.

COMPUTER SUPPORT

Develops digital computer programs for apportionment, prediction, and assessment. Develops the storage and retrieval system for test data, and the statistical computer programs for evaluation of these data.

ADMINISTRATIVE & TECHNICAL STAFF

Responsible for all administrative aspects of the total Apollo reliability program.
Responsible for all reliability aspects of discrete vehicles and associated GSE as assigned.

APOLLO DESIGN REVIEW
SUPERVISOR
R. W. Swigart

Establishes and implements formal design reviews of the subsystems and end items of the Apollo SC and GSE.

- Schedules and organizes design review meetings coordinates with the departments concerned to obtain material required for design review board (DRB) evaluation.
- Distributes review material to the DRB members in sufficient time to allow adequate evaluation and to complete premeeting coordination.
- Monitors the preparation of design review meeting agenda items to insure satisfactory handling of all DRB member items to be considered.
- Prepares DRB meeting reports. Maintains current status report of all action required by the board.

CRITERIA AND EVALUATION
CHIEF
Rails

Conducts statistical analysis; establishes technical requirements and controls; conducts reporting and coordination to assure reliability integration of the Apollo Project.

MATH AND STATISTICAL ANALYSIS

- Provides statistical support in development of reliability apportionment, prediction and assessment models, machine programs and techniques.
- Computes and prepares displays of reliability and crew safety growth.
- Provides statistical support to the development of test programs and plans.
- Provides consulation to subcontractors and suppliers on statistical matters, computer programs and mathematical models.

TECHNICAL REQUIREMENTS

- Evaluates and coordinates environmental design and test criteria. Coordinates and defines manufacturing and quality control requirements for specifications.
- Conducts reliability evaluation on pre-award surveys.
- Coordinates program requirements with and assignments to General Data Center, Reliability Education Unit, Component Technology, Quality Control, and other agencies.
- Provides management and NASA with data and reports relative to administrative and technical progress of the complete Apollo reliability program.
- Plans and implements administrative and documentation controls.
- Reviews, evaluates and processes contractual changes.

ELECTRONIC AND INTEGRATED SYSTEMS
CHIEF
M. E. Wheelock

Establishes and implements an integrated reliability program for Electronic Subsystems and combined systems of the Apollo spacecraft to assure maximum reliability and safety in initial designs and maintenance of these through manufacturing and field operations.

SPACECRAFT SYSTEMS

- (Responsibilities and functions are identical to those of the Electro-Mechanical Systems and GSE unit.)
- Supports MSC/MSFC Crew Safety Systems Panel.

INTEGRATED SYSTEMS

- Defines and maintains the overall math model and reliability and crew safety logic diagram for the integrated spacecraft, LEM and associated ground equipment.
- Defines and maintains the math model and machine programs for reliability apportionment, preduction and assessments by mission phases.
- Conducts reliability & safety trade-off studies involving the mission or total spacecraft.
- Evaluates interface problems with ramifications in reliability or crew safety.
- Acquires reliability and crew safety improvement and assessment data from field tests.
- Writes field failure and problem report and conducts "on-the-spot" failure analysis.

ELECTRO-MECHANICAL SYSTEMS AND GSE
CHIEF
H. L. Steverson

Establishes and implements on integrated reliability program for Spacecraft Mechanical and Electro-Mechanical Subsystems and GSE to assure maximum reliability and safety in initial designs and maintenance of these through manufacturing and field operations.

SPACECRAFT SYSTEMS & GROUND SUPPORT EQUIPMENT

- Generates and maintains reliability and crew safety logic diagrams and math model on S&ID designed equipment; reviews logic diagrams and math models Defines reliability and crew safety requirements and numerics for specifications and engineering documents.
- Analyzes S&ID designs and spot checks subcontractor analyses for reliability and safety ramifications, compliance with requirements and improvement recommendations.
- Conducts trade-off studies to determine reliability and safety influences of weight and cost reduction measures, manned provisions, alternate modes of operation, on-board spares, and in-flight maintenance.
- Conducts and documents failure mode and effect analyses.
- Monitors subcontractor and supplier reliability programs, efforts and accomplishments via technical coordination meetings, document reviews and plant visitations; provides consultation and recommends reorientation, as required.
- Prepares remedial recommendations on problem and malfunction reports or coordinates preparation of the same with subcontractor and supplier personnel.
- Evaluates reliability sections of subcontractor and supplier proposals and estimates; supports source selection.
- Provides assistance on training and interface problem resolution in manufacturing and quality control areas.
- Conducts program audits; recommends technical and management reorientation or concentration of effort; progress and evaluation reports.
- Conducts interface studies to assure reliable integration of GSE and associate contractor equipment with S&ID portions of Apollo.
- Defines tests criteria and reliability requirements for test sections of equipment procurement specifications and Apollo test plans.
- Establishes requirements for test facilities.
- Assists in the selection of test agencies.
- Monitors all S&ID and supplier test programs.
- Writes detail test procedures.
- Approves S&ID and supplier test installations.
- Reviews all test documents and data for validity and applicability.
- Prepares tests reports, recommendations and conclusions.
- Relates test data to reliability and crew safety assessments.
- Maintains qualification status records of all subsystems, subassemblies, components and parts.

Figure 1-4. Apollo Reliability Organizational Responsibilities

Central Reliability Functions

Product Assurance and Support Services provide centrally located support functions for Apollo Reliability, with specialists in the following specific areas. Component-Technology provides support by evaluating and maintaining reliability data and specifications on preferred and common usage parts. Product Requirements aids in determining and documenting contamination control requirements, preferred manufacturing processes and methods to be used in the assembly of parts and components. Product Controls provides support in the continuous surveillance of part and component manufacturers as well as installation, handling, packaging, identification and traceability processes for preferred and common usage parts and components. Reliability Education provides educational and motivational material for those employees whose work influences reliability. Computer Support develops Apollo Reliability computer programs, including data storage and retrieval systems.

Other Support Functions

Test and Quality Assurance organizations that provide support to Apollo Reliability are Apollo Data Control and Value Engineering. Apollo Data Control provides a central data function which develops systems to maintain, process, and report data originating in Apollo Reliability. Value Engineering provides support in cost reduction and value analysis associated with Apollo design reliability.

RELIABILITY MILESTONES AND STATUS

Figures 1-5, 1-6, and 1-7 show the status of completed and scheduled reliability milestones. The milestones are periodically updated and submitted per contract agreement.

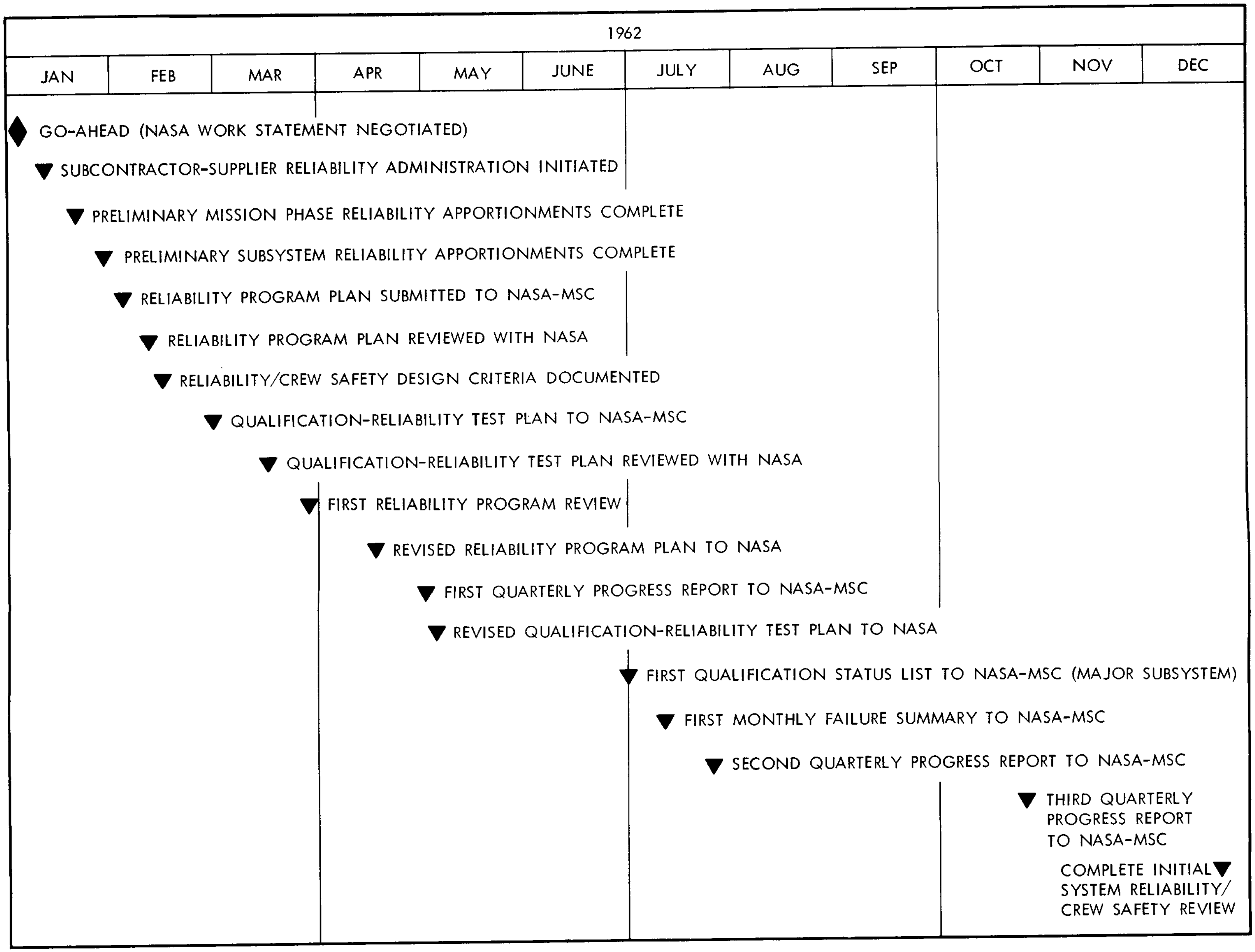

Figure 1-5. Reliability Milestones and Status, 1962

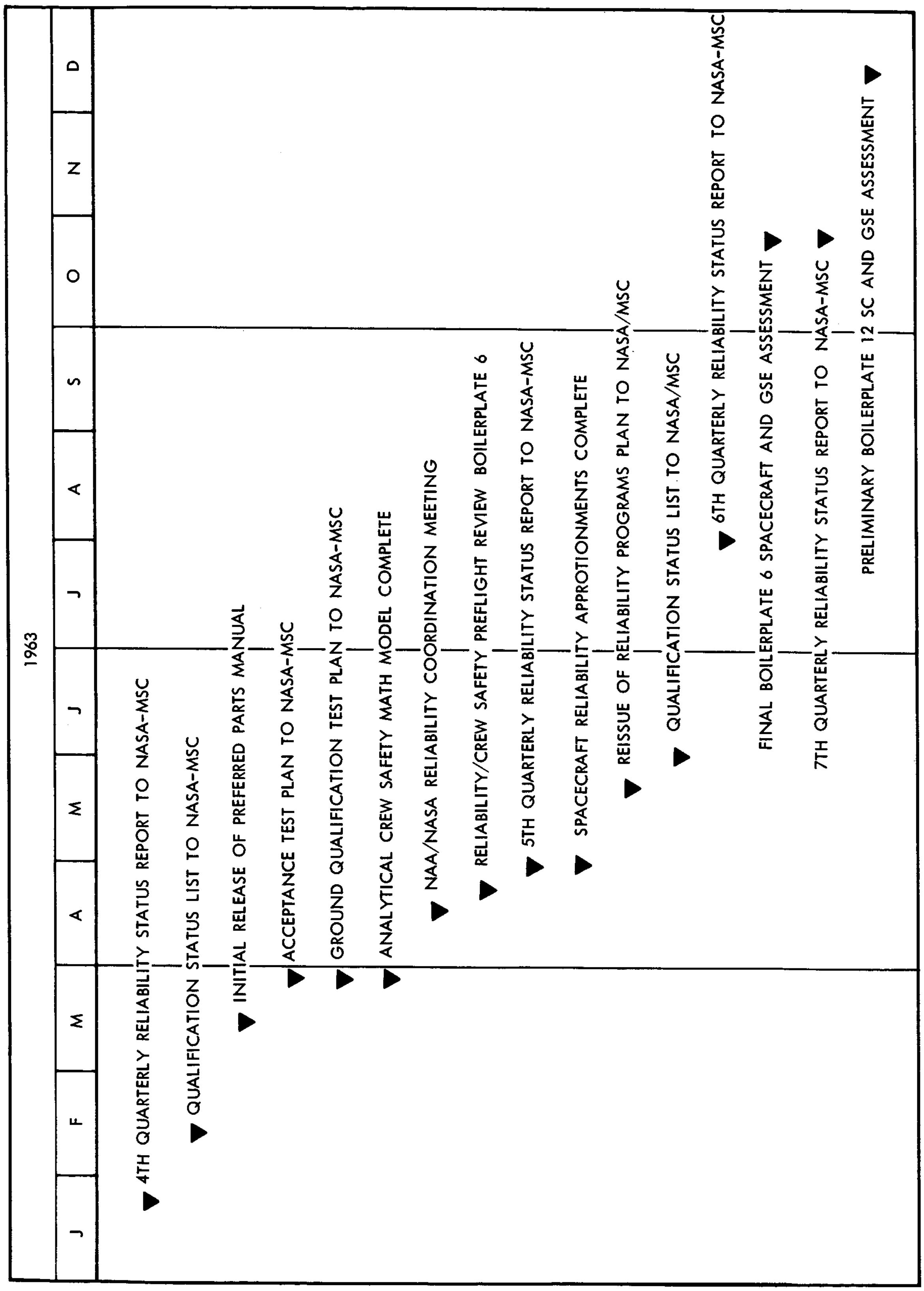

Figure 1-6. Reliability Milestones and Status, 1963

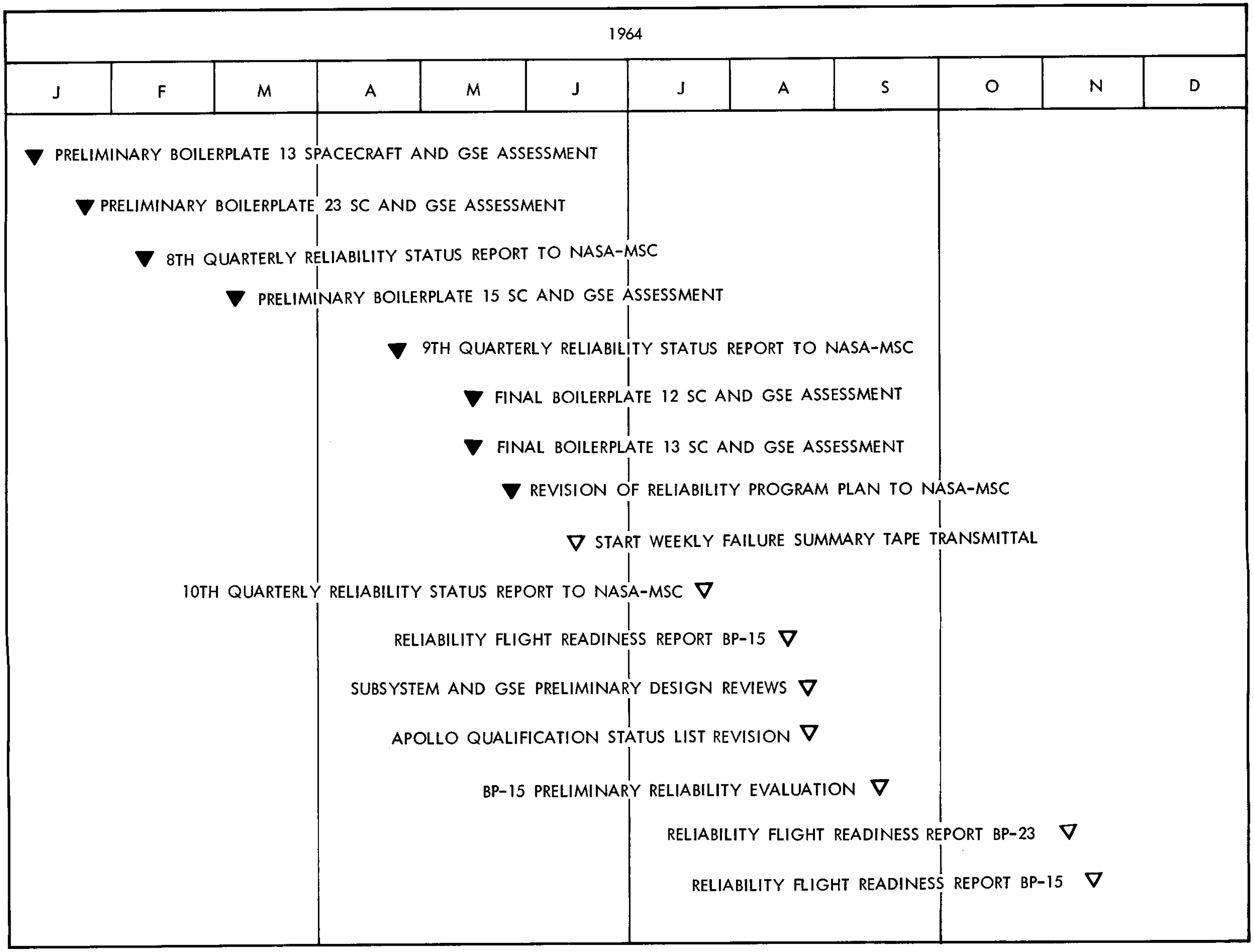

Figure 1-7. Reliability Milestones and Status, 1964

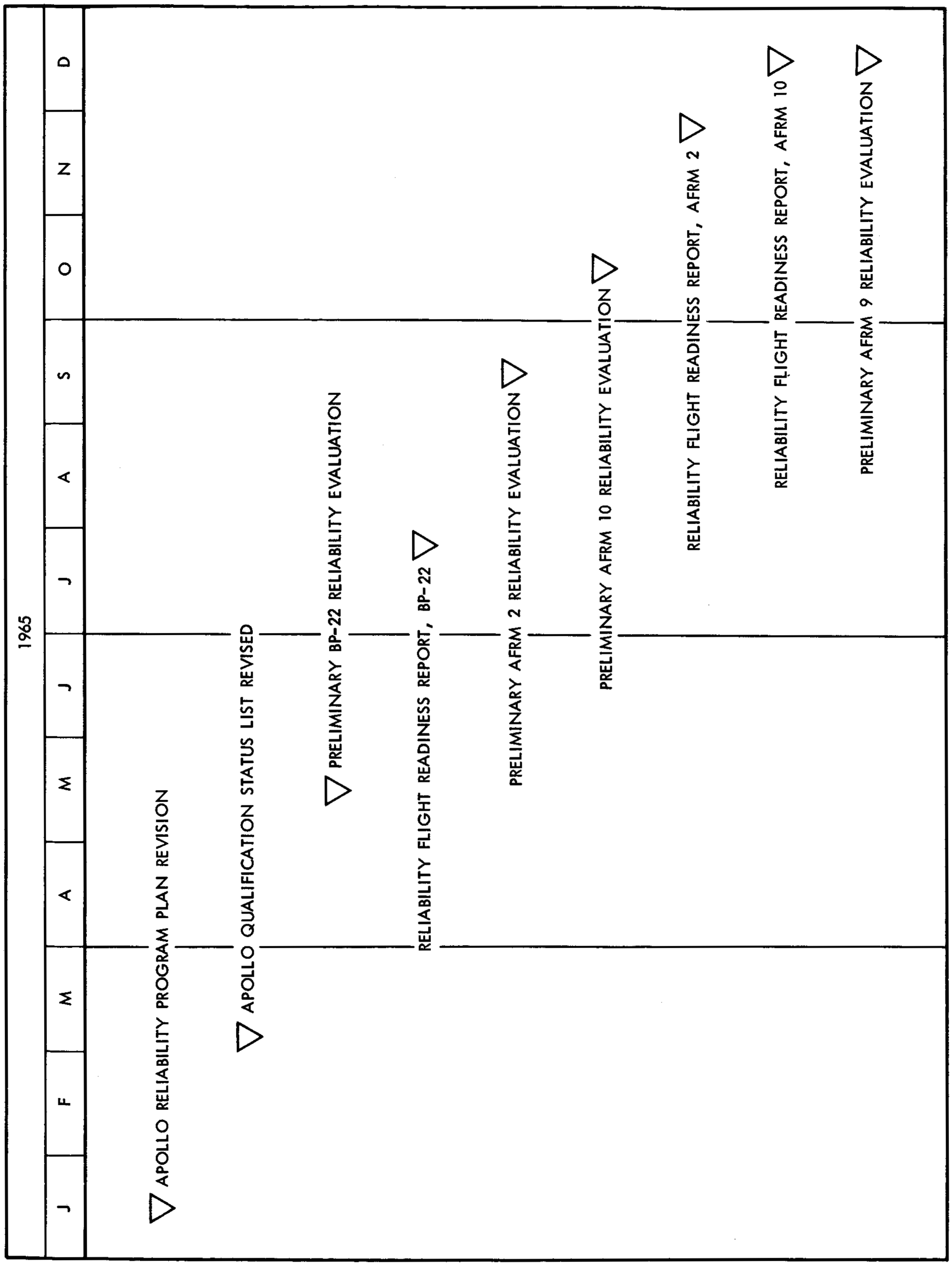

Figure 1-8. Reliability Milestones and Status, 1965

III. DESIGN RELIABILITY

One of the primary objectives of the Apollo development program is to enhance achievement of the reliability and crew safety goals prior to the first manned flight. To attain this objective, every available reliability design technique must be used. Some of the high-integrity techniques that will be employed are adequate design margins, system simplification, fail-safe provisions, redundancy, in-flight maintenance, and the use of the crew in primary and redundant system functions. The methods utilized are discussed in the following paragraphs, along with the analysis techniques for assuring adequate design.

Early in the Apollo design stage, an investigation will be made to determine the mechanization of each subsystem that will be used to meet the objectives. In arriving at proper mechanization, extensive trade-off studies will be made of the requirements in performance, weight, volume, reliability, and cost. The mechanization decisions that are established for Apollo are presented in the Design Criteria Specification (report SID 62-65).

ENVIRONMENTAL CRITERIA AND REQUIREMENTS

The environmental design and test criteria for the Apollo program is established by Apollo Technical Manual, SID 64-185 (ARM-8), by direction of the Chief Engineer of Project Apollo. This document describes the various environmental conditions to be encountered and defines or references the general criteria for determining the applicability of the various environments to the Apollo program. Although the criteria presented are generally applicable to the design of the spacecraft and associated ground support equipment, specific analyses are performed for each system, subsystem, and equipment. Any resulting deviations, when justified and approved, are documented in the appendix of this manual. General coordination and evaluation of environmental criteria is achieved by the ARM-8 Manual Review Board under the chairmanship of the Manager of Technical Operatio..s. The Review Board is comprised of representatives from Apollo Reliability Engineering, responsible Apollo design analysis groups, and various Aerospace Sciences support groups. The basic source of environmental design and test requirements defining environmental levels and durations for incorporation into procurement specifications are established by S&ID general specification MC999-0051, Apollo Environmental Design and Test Requirements. Apollo Reliability Engineering is responsible for coordinating and providing detailed environmental criteria and requirements which are incorporated into the above documents and disseminated to Engineering.

PREFERRED PARTS

Parts Manual Volume 4

The S&ID Parts Manual Volume 4 has been developed to control parts used in the system by means of optimum part selection, correct part design application, controlled part procurement, appropriate part handling methods, including packaging, transportation, storage, identification and traceability, necessary part processing and installation controls, and total past history and data surveillance.

Each S&ID preferred part listed in Volume 4 of the Parts Manual is available in two quality levels: S&ID high reliability, and general usage. Procurement specifications control each part level and are invoked by control numbers listed on the first page of the application data sheets for each part. The two quality levels are physically and functionally equivalent. The S&ID high-reliability level parts are used in design areas where reliability is a critical consideration, whereas noncritical applications utilize the general usage level parts.

Electronic Parts

The efforts of previous space projects, in addition to the Apollo program to reduce the failure rate of electronic parts, have resulted in parts with a reliability one to two orders of magnitude greater than previously available. This increase in the reliability of parts has been the result of complete documentation in manufacturing and quality control procedures and the determination and minimization of all possible failure modes for each device. As new failure modes are encountered, the materials, processes, or environments that induce the failure mode are reviewed, revised, and documented to preclude recurrence. Statistically designed experiments and accelerated tests are extensively employed to expose various failure modes and evaluate the effectiveness of the corrective actions.

The techniques employed become part of the procurement specification, so that all suppliers will continuously improve the parts being used in the system. Procurement specifications employ tests on either a lot or daily sampling basis to ensure that the parts produced by each supplier meet minimum requirements for environmental, accelerated-life, and usage conditions. The part failure rate under application or accelerated conditions is verified at a 60-percent confidence limit at various intervals throughout the program.

Parameter Stability Data

The failure of a part can be attributed either to a catastrophic failure caused by a short or open condition of one of the major elements of the device or to a change in one or more of the operating parameters beyond prescribed limits. The catastrophic failure mode can be eliminated only by the manufacturer through rigid process and quality control methods during the manufacturing cycle, coupled with a complete knowledge of the various steps of the process where an incipient catastrophic failure mode can be introduced into the product. Drift can generally be compensated for by the circuit designer's ensuring that the maximum drift will not cause a circuit or system failure.

An extensive program has been implemented to determine and optimize the stability and/or variance of important parameters under various combinations of electrical and temperature stresses. This program yields information on the statistical distribution of variables as a function of time that is made available to design engineers and is employed in the analysis of various circuits during the preliminary design period. Combined supplier and consumer data are used to evaluate the effect of electrical and environmental stresses, for short or long periods of time, on the failure rate at specified parameter limits.

Use of Minuteman Parts

Considerable background in parts reliability improvement techniques has been gained from the Minuteman program. However, before any Minuteman part will be accepted for Apollo use, it will be determined that the known failure rate and environmental capabilities of the part are compatible with Apollo requirements. In lieu of repetitive tests, the maximum available data will be screened for application suitability on Apollo.

Electromechanical Parts

The reduction of failures of electromechanical parts having an apportioned failure rate consistent with Apollo requirements will require a diligent program, vigorously pursued, through the entire life of the equipment.

Expected Failure Modes

The expected failure modes of electromechanical parts include surface wear, fatigue, corrosion, degradation with time, and lubricant failures, most of which are amenable to analytical methods of evaluation and resolution. However, little is known concerning the quantitative effects of minute variations and imperfections on the mechanics of failure. This lack of data develops a multitude of indeterminates. For this reason, the application and usage of electromechanical parts for the Apollo program must involve critical attention to the smallest details to minimize the influence of these indeterminates.

In some instances, parts must be designed for the specific application at the sacrifice of the economics of standardization. In other cases, part improvement effort may be required to advance the state of the art so that desired reliability goals can be approached. A noncompromising philosophy of raw material control that will preclude the use of faulty material will be developed. Extremely rigorous in-process controls will be implemented to obtain the ultimate in fabrication techniques, dimensional control, surface finish requirements, manufacturing processes, and other criteria necessary to yield a consistent part having an absolute minimum of minute variations.

ANALYSIS TECHNIQUES

Estimates of Design Reliability

Equipment Reliability

The reliability of equipment is dependent upon the environment and operational conditions to which the equipment is subjected. A preliminary estimate of these conditions will be made by design and reliability engineers, based on classical techniques.

It is assumed that the equipment has been started and is operating, that no unfavorable transients are experienced during the starting operation, that the parts are free of "infant mortality" or wearout, and that the failure rate is constant. The reliability of the parts is assumed to be the exponential with respect to time as given by the estimator,

$$R = e^{-\lambda t}$$

where

λ = Failure rate

t = Operating time

This assumes that all parts are connected in series and that a failure of any one part will result in loss of function within the subject equipment. Under these assumptions there is justification to permit multiplying the probability of success P_s values or adding the failure rate values for each part. A typical example employing this reliability prediction technique is given in Figure 3-1.

If the equipment is started while in flight or is subjected to on-off cyclic operations, then the reliability is the product of probabilities of starting and operating, or

$$R = e^{-nr} (e^{-\lambda t})$$

where

n = Number of required starts

r = Ratio of unsuccessful starts to start attempts

8. Reliability apportionment and prediction reports
9. Completed detailed reliability analysis and assessment
10. Completed procurement specifications
11. Maintenance plans
12. Human engineering analysis
13. Systems integration analysis

Special Design Review

In addition to the regular sequential design reviews, the Design Review Board Chairman may, upon receipt of recommendations from any of the permanent Design Review Board members, schedule a special design review. Special end item reviews of boilerplates and spacecraft are conducted on a preliminary and preflight basis. Written justification is required to substantiate special design review recommendations. Special design reviews are conducted to review S&ID or supplier designs not included in the regular design review schedule, changes in design or design application, quality, manufacturing, test or operations problems affecting design, and end item or associate contractor interface designs.

Depending on the nature of the design, special design reviews may be completed in one stage or may require scheduling the normal three sequential reviews.

Data requirements for special design reviews are designated by the Design Review Board chairman and include, but are not limited to, the requirements established for preliminary, major, or application approval design reviews.

REVIEW CHECKLIST

The Checklist for Design Review, Apollo, used during the design review, is contained in SID 64-568.

AREAS TO BE REVIEWED

Design reviews will be accomplished on all spacecraft subsystems and equipment as well as mission essential ground support equipment and end items of spacecraft and boilerplate test hardware.

BOARD MEETING DISPOSITION

Disposition of a design is made during the Design Review Board meeting as follows:

1. Design approved without qualification

2. Design approved, subject to satisfactory resolution of action items

3. Design approval withheld. Approval may be withheld for lack of sufficient data to evaluate the design, interface problems, material considerations, etc. A review must be scheduled to cover areas requiring improvement

4. Design disapproved. Complete inadequacy is required to disapprove a design. Another review of the modified or changed design approach is necessary

5. When one or more board members strongly disagree with the remaining board members, a minority report is submitted to the Chief Engineer

Problems which the board is unable to resolve are referred to the Chief Engineer. In these instances, the Design Review Board chairman provides all of the necessary data, including clear definitions of the problem areas.

The Chief Engineer takes such action as necessary to resolve the problems. The design is then reviewed again by the board. In all instances, final authority rests with the Chief Engineer.

REVIEW REPORTS

The chairman of the Design Review Board is responsible for the preparation of reports documenting Design Review Board activities. These reports are submitted to the Chief Engineer, Design Review Board members, and meeting participants, and summarize the data submitted to the board for design review and reflect board dispositions, corrective action taken, and board approvals.

V. RELIABILITY MONITORING AND DOCUMENTATION

Timely reviews of progress, status, data, and reports are essential to the successful implementation of corrective action and the management of the program. Accordingly, a reliability monitoring, program review, documentation, reporting, and data processing system has been established to provide NASA and S&ID functional organizations and management with significant information and guidance upon which decisions can be based.

MONITORING

The Apollo Reliability Manager is responsible for monitoring the progress of all reliability activities, including preparing and submitting to higher management all reliability documents and reports. He will also review and approve other reports related to reliability and containing reliability information.

The paragraphs that follow delineate the responsibilities and the scope of the data program and activities as applicable to Apollo.

Reliability Manager

The Apollo Reliability Manager will keep informed of reliability program progress by continuously monitoring and periodically reviewing all reliability activities. The data and reports generated by the documentation and reporting system will be his source of information. From these and other sources, the manager will determine whether the reliability/crew safety objectives are being attained, that the program plan continues to be adequate as it progresses, and that all work affecting reliability is being performed in accordance with the program plan. He will also determine whether past reorientation has been effective and whether control measures and corrective actions are adequate.

The Reliability Manager will provide reliability program progress information and data for periodic MSC technical and management program progress reviews.

Formal determinations of progress will be made and published in the quarterly reliability report along with implemented or recommended corrective action as applicable. Charts, including those showing achieved reliability versus reliability growth objectives, will be maintained and continuously displayed.

Reliability Data

Reliability data will be extensively employed as a management tool for control and direction of the Apollo program. Data are continuously accumulated, collated, and analyzed to show trends and status and to allow predictions in all development and test areas. Reliability data, its acquisition and flow for management purposes, as well as for technical and analytical purposes, is indicated in Figure 5-1. A description of nonconformance and failure reporting, nonconformance analysis reporting, and corrective action reporting systems appears in Section VIII of this plan. S&ID specification MA0201-0077, Time Significant Item List, establishes time/cycle significant items for boilerplates, spacecraft, ground support equipment, and Government-furnished equipment. It further defines operating time and shelf life and provides a method for collection of data for reliability evaluation and assessment.

Data Center

The primary function of the data center (Apollo Data Control) is to establish and maintain a central S&ID operation for acquisition, processing, storage, retrieval, and dissemination of data from Design, Test, Manufacture, Inspection, Subcontractors, Associate Contractors, and Operations areas. Figure 5-2 is a typical schematic presentation of Apollo Data Control central data function.

Basic equipment to be employed in data processing will consist of the IBM 7094, 1401, 1410, and 1301 and the Stromberg Carlson 4020 computers, supplemented by a portable IBM 1620 for increased flexibility. These computers are programmed to provide information and compilations and to perform special search and analysis functions, such as the following:

Nonconformance reporting data for corrective action and follow-up
*Evaluation and analysis for design or quality improvements, reliability audits, and progress reporting
Component usage data
Equipment functional histories
Supplier quality history lists
Reliability assessments
Correlation of failure mode and cause data
Configuration and serialization records
Operating time records
Subcontractor and supplier ratings
Qualification status reports

*Parameter variation, worse-case analysis, logic networks, failure mode analysis, Monte Carlo analysis, etc.

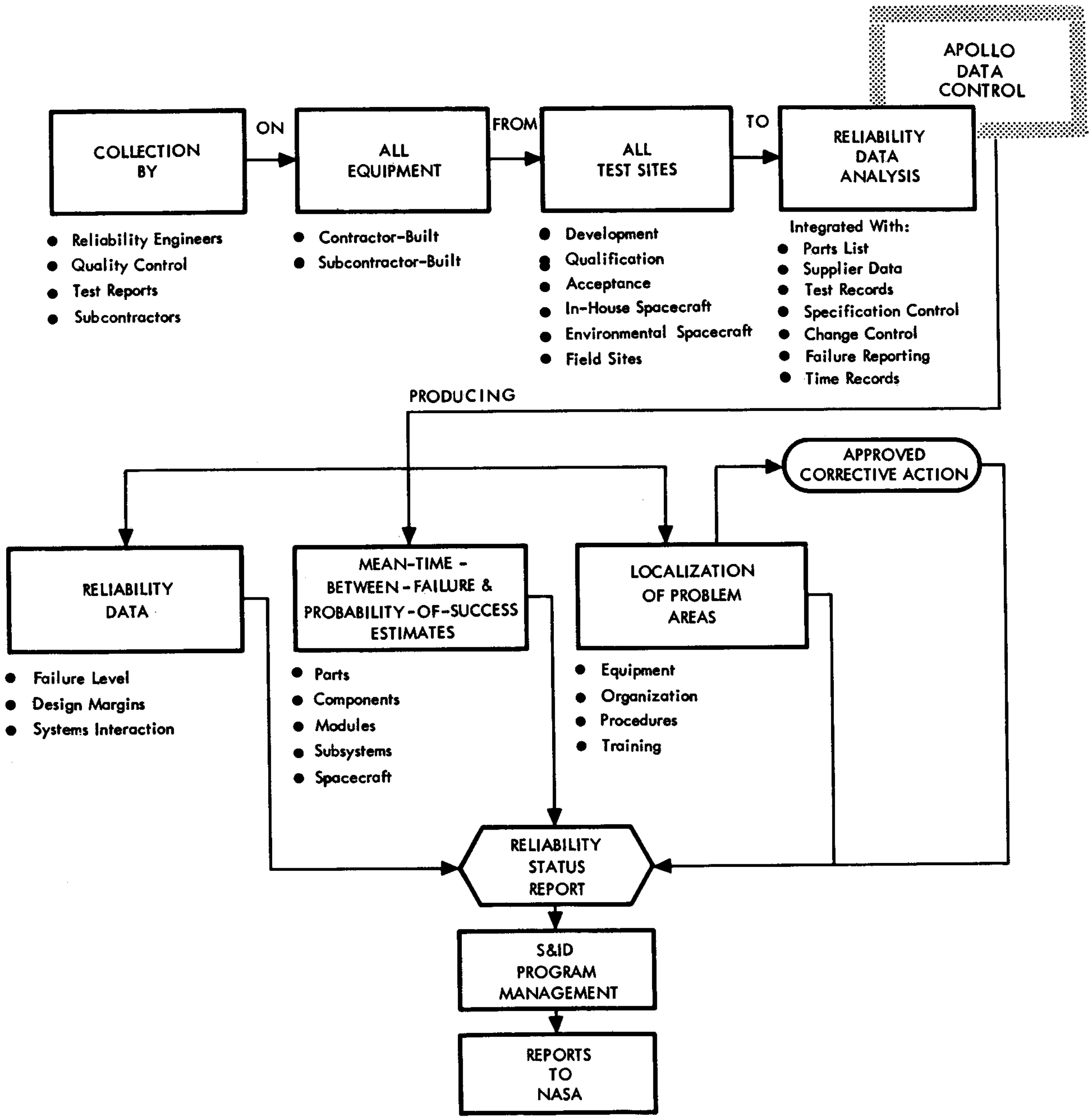

Figure 5-1. Data Acquisition and Analysis Flow

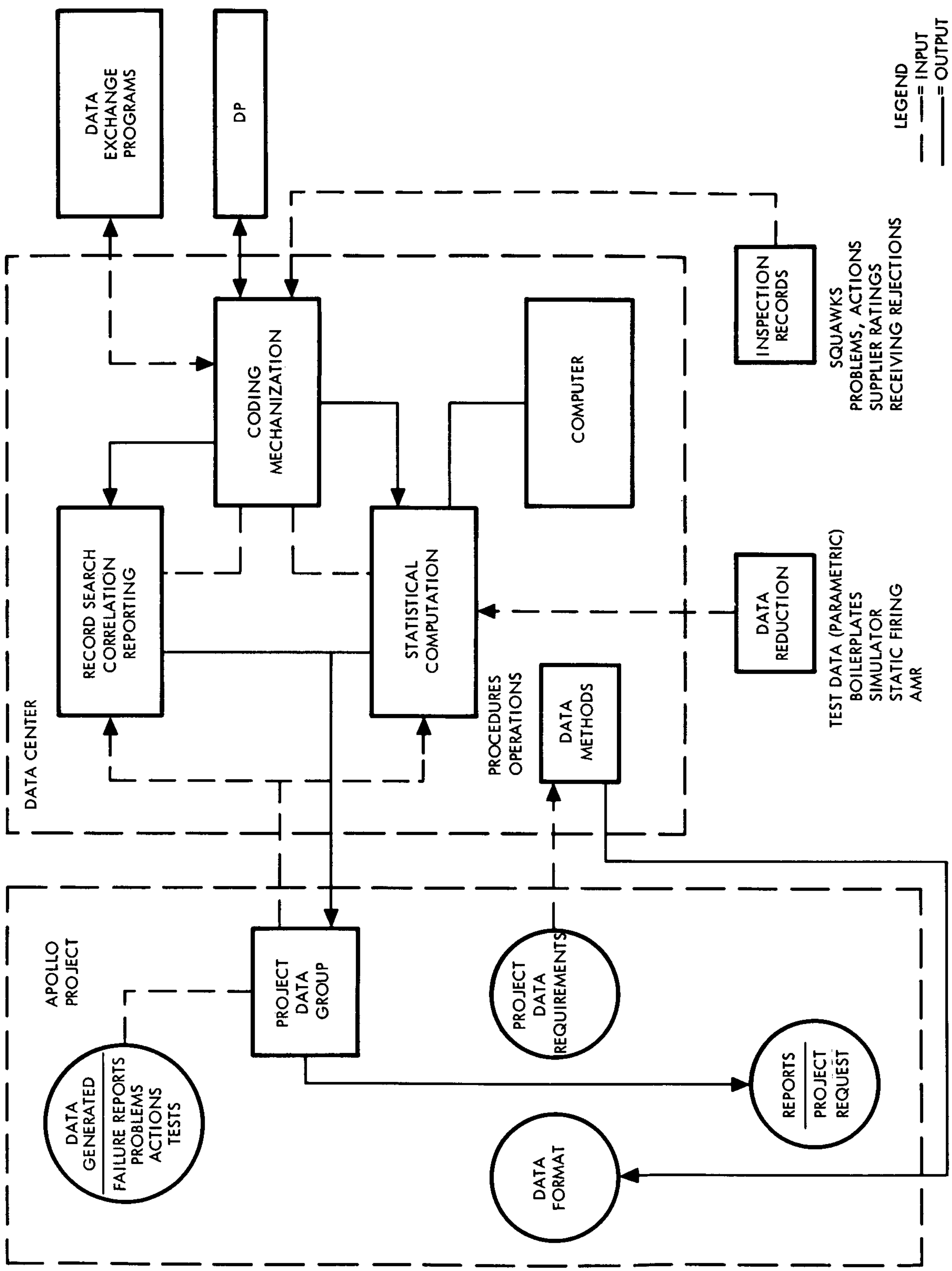

Figure 5-2. Apollo Data Control, Central Data Function

Specification lists
Test results
Corrective action summaries and status
Critical and limited-life parts list

These data are periodically distributed to those directly affected.

Computer Support

The Computer Support Group under the direction of the Reliability Director is responsible for writing, documenting, and maintaining the digital computer programs required by Apollo Reliability for apportionment, prediction, assessment, and the statistical evaluation of data. Technical requirements for the digital programs are originated within the appropriate Apollo Reliability area under guidance of the Apollo Reliability Manager.

DOCUMENTATION AND REPORTING

The documentation and reporting system provides periodic reports for S&ID and NASA to permit a continuous accounting of reliability progress and problems throughout the program. Reliability documentation and reporting are in accordance with Exhibit I of the Definitive Contract NAS9-150 and include the documents listed in Appendix E. Documentation and reporting requirements of specification MIL-R-27542 are met by including the desired information in reports required by Exhibit I of the Definitive Contract NAS9-150.

VI. ASSOCIATE AND SUBCONTRACTOR RELATIONSHIPS

This section establishes the means for assuring that the reliability of subcontracted work and the work of associate contractors is consistent and compatible with over-all system objectives.

ASSOCIATE CONTRACTORS

NASA will select associate contractors for the lunar excursion module, navigational and guidance system, flight research and development instrumentation, scientific instrumentation, and NASA-furnished crew equipment. Consistent with NASA requirements the Apollo Reliability Manager will determine the scope of effort required to assure compatibility of S&ID-associate contractor interface and integration requirements. Under his direction, Reliability Engineering personnel will accomplish the following:

1. Maintain effective liaison between associate contractor and S&ID and assist them in the solution of reliability problems
2. Participate in a joint effort with associate contractors and, in close coordination with NASA-MSC, specify in detail requirements for module and equipment interfaces with ramifications in reliability or crew safety
3. Advise NASA on the acceptability of associate contractors' designs for compatibility with over-all spacecraft reliability and safety requirements
4. Coordinate on integrated systems reliability and crew safety analysis
5. Coordinate data requirements and data exchange
6. Coordinate and establish common usage components and parts lists
7. Coordinate test planning to assure program optimization
8. Provide associate contractors with reliability feedback information

MAJOR SUBCONTRACTORS

Major subcontractors are required to establish a reliability program in consonance with paragraph 2.4 Exhibit A of the Definitive Contract NAS 9-150 and military specification, MIL-R-27542, and to prepare reliability program and qualification test plans. Plans are reviewed and approved by S&ID. Currently designated as major subcontractors are the following:

Aerojet-General	Service propulsion subsystem
AiResearch	Environmental control subsystem
AVCO	Heat shield
Beech Aircraft	Cryogenic storage subsystem
Collins Radio	Telecommunications subsystem
Lockheed	Launch escape motor
Marquardt	Service module reaction control subsystem
Minneapolis-Honeywell	Stabilization and control subsystem
Northrop-Ventura	Earth-landing system
Pratt & Whitney	Fuel cells
Rocketdyne	Command module reaction control subsystem
Thiokol	Escape tower jettison motor
Autonetics	Spacecraft instrumentation test equipment
	Acceptance checkout equipment

The reliability programs of each major subcontractor are essentially the same, since all are based on the requirements of MIL-R-27542 and NPC 200-2 and require NAA/S&ID approval prior to application to the Apollo Program. Some variations occur, however, because subsystem characteristics are different, the state-of-the-art is more advanced, or the subcontractor's reliability requirements are more stringent. Such factors have been brought to light in the preaward subcontractor reliability surveys. The scope and format for preaward surveys are defined in Appendix F. All controls, provisions for liaison and surveillance, documentation and reporting, data analysis, review, training, and motivation are established and delineated in detail in the Statements of Work, Documentation Requirements Specifications and in the required plans. Consistent with NASA requirements, the Apollo Reliability Manager determines the scope of contractor reliability programs and efforts. Under his direction, Reliability Engineering personnel will accomplish the following:

1. Assist pertinent functional divisions in the selection of qualified subcontractors and suppliers

2. Prepare reliability requirements for statements of work, documentation specifications and procurement specification for subcontracted items

3. Evaluate proposals from potential suppliers of Apollo equipment. Support contract negotiations on reliability activities.

4. Monitor subcontractor reliability and test effort

5. Review and approve subcontractor reliability program, acceptance and qualification test plans

6. Maintain effective liaison between subcontractors and S&ID and assist them in the solution of reliability problems

7. Provide subcontractors with reliability feedback information

8. Provide reliability inputs to and review reliability portions of procurement documents prior to release

Monitoring and Coordination

Reliability engineers with specialized experience in the various subsystems are assigned to monitor reliability program progress at each subcontractor. The reliability engineer provides liaison between the subcontractor and S&ID.

Subcontractor reliability programs are evaluated periodically using the S&ID Apollo Project Subcontractor/Supplier Reliability Program Evaluation SID 64-8. The objectives of this audit are to:

1. Determine effective reliability program coverage in terms of specific contractual requirements.

2. Determine effective reliability program coverage in terms of Apollo manned space flight program needs.

3. Inform, indoctrinate, and update subcontractor/supplier reliability personnel in detailed Apollo reliability program requirements.

4. Make recommendations for improving, strengthening, or reorienting the reliability program elements.

5. Evaluate, through successive surveys, changes in effectiveness of reliability program activities.

The subcontractor/supplier reliability program evaluation questionnaire comprises the following parts:

I. Organization and Management

II. Over-all Policies, Procedures, and Program Planning

III. Design Analysis

IV. Design Review

V. Test Operations

VI. Internal Document Control

VII. Procurement Control

VIII. Production Support

IX. Failure Analysis and Corrective Action

X. Communications, Reporting, and Support to S&ID

XI. Education and Motivation

During an evaluation, the S&ID Reliability Engineer interviews various members of the subcontractor's staff to get several viewpoints on implementation of their reliability program.

<u>Control</u>

Before a major subcontractor is authorized to proceed with design or production, the following prerequisites must be met.

1. The subcontractor's engineering, reliability, manufacturing, and quality control personnel and capabilities are suitable for the development and/or production of highly reliable spacecraft or ground equipment.

2. The design is approved by S&ID for reliability, function, and manufacturing and quality feasibility.

3. The subcontractor's quality control and inspection plans are approved by S&ID.

4. The test plans and facilities used by the subcontractor are approved by S&ID.

5. The subcontractor's reliability program plan adequately sets forth the subsystem reliability approach and objectives.

6. Commensurate requirements and controls are transmitted to sub-tier suppliers

After authorization to proceed, the subcontractor's activities are under the surveillance of S&ID resident Quality Assurance (representing Reliability and Quality Control) and Design personnel. Close scrutiny is maintained over each element of the various program plans. Precise controls and documentation requirements serve as the basis for program analysis and review by both the subcontractor and S&ID.

Training and Motivation

Subcontractors are required to provide indoctrination and training in reliability and quality for all employees. Initial orientation briefings are given at the time individuals are assigned to the Apollo project. Briefings continue periodically for the duration of the program. The purpose of the briefings is to establish an understanding of the Apollo missions, to point out the relationship of the hardware and personnel to completion of this portion of the national space program, and to establish the motivation to guarantee excellence of job performance. Through training activities, subcontractors will establish and sustain high skill levels for personnel associated with all phases of development, production, and test. Symposia are presented by S&ID for subcontractors to provide educational material and for program requirement clarification. Additionally, subcontractors are provided with publications, films, guidance and training course material to develop a reliability educational program. A description of S&ID's responsibility for subcontractor indoctrination and training is given in Section X.

OTHER SUBCONTRACTORS AND SUPPLIERS

Depending upon the reliability requirements and the complexity of the item to be purchased, the Apollo Reliability Manager establishes the requirement for a formal reliability program at other subcontractors and suppliers. The reliability requirements in the Statement of Work or procurement documents specify the extent of the program. For suppliers, the procurement specification may require that specific paragraphs of MC-999-0067 (Reliability Program Requirements for Apollo Suppliers) be met depending on the type of procurement.

S&ID suppliers and subcontractors are provided with an NAA accepted statistical method for determining the test correction factor to account for lack of precision or repeatability in the test equipment and test personnel. This method is documented as SID 64-25, Implementation of Instrumentation Accuracy Criteria for Apollo, dated 17 January 1964.

VII. TEST AND RELIABILITY ASSESSMENT

The Apollo test program is an integrated plan designed to provide for maximum utilization of data from each test area for developing and qualifying hardware and assessing achieved reliability of the spacecraft and GSE. Laboratory, ground spacecraft, and flight tests compliment each other to provide assurance that equipment will perform its intended functions during the manned phases of the program. Details of this test plan are contained in the Apollo General Test Plan, SID 62-109.

TEST PLAN DESCRIPTION

The high reliability and safety objectives, a desire for an assessment of achieved reliability, and the variety of mission environments make the performance of a single test to satisfy these requirements economically impractical. S&ID intends that most testing at the part, component, subsystem, and system levels be used to assess reliability and crew safety. Figure 7-1 defines the different phases of the overall Apollo test program and the approximate percentages of data from each test area applicable to the assessment of reliability. Although these percentages will vary with each item considered, they are representative of the expected averages.

The integrated test plan for Apollo is a consolidation of a sequence of tests starting with certain material evaluations and proceeding through actual flight and recovery of the spacecraft. Figure 7-2 illustrates the integration of the qualification tests into the overall test plan. Qualification testing of materials, parts, components, subsystems, and systems under functional and environmental stresses will, in general, follow development tests but will include certain development test results. Qualification tests will be conducted to ensure that the design is capable of meeting anticipated Apollo LOR mission requirements. Other tests on nonflight hardware will demonstrate capabilities of integrated systems and the complete spacecraft and their reliable operation under simulated LOR flight performance and environmental conditions.

Acceptance tests on flight hardware will verify that the performance, reliability, and quality of parts, components, subsystems, and spacecraft, as manufactured, are equivalent to previously approved items. The standards against which these items are compared will be determined from the results of development and qualification tests.

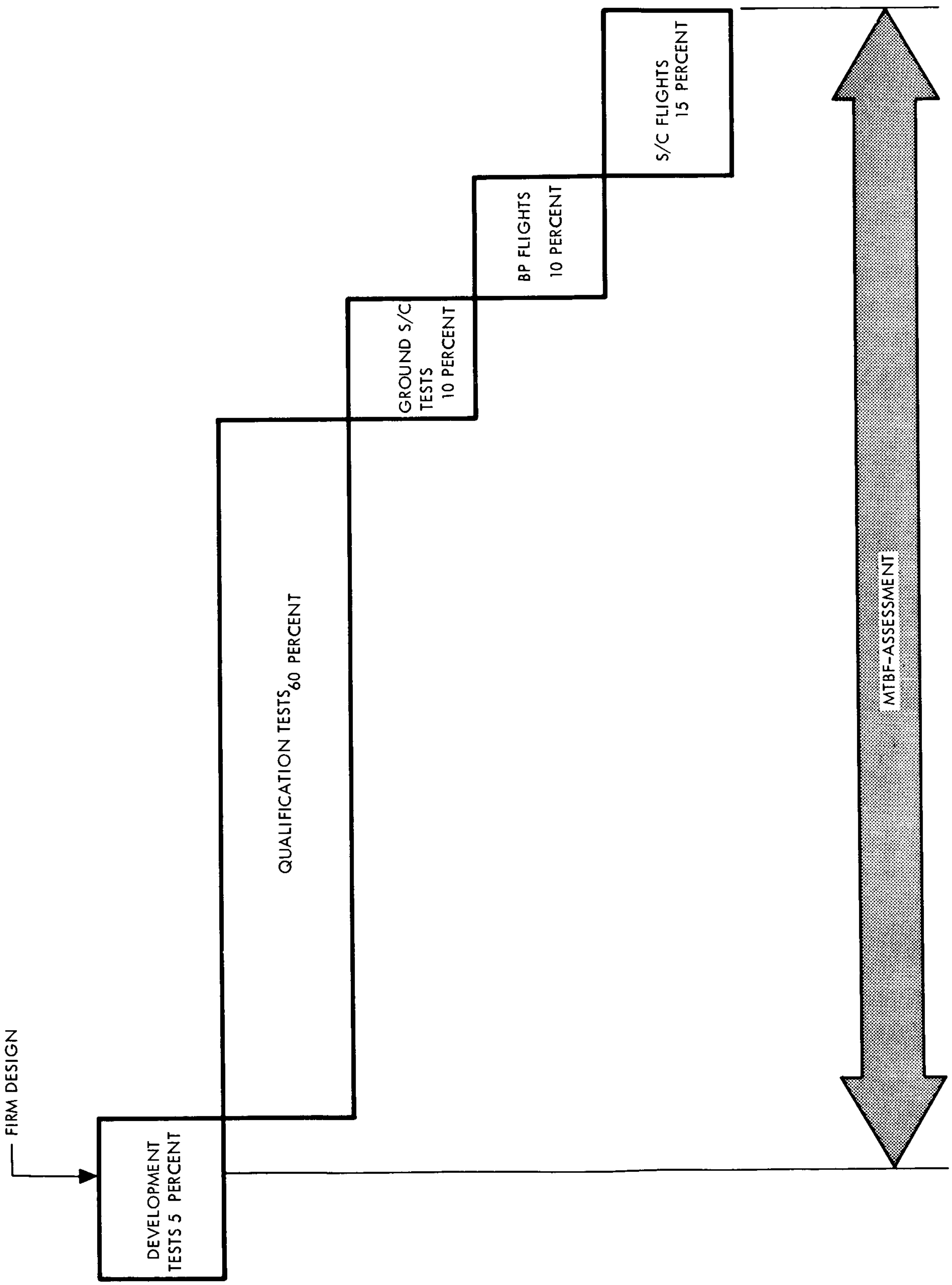

Figure 7-1. Reliability Assessment

Preliminary Assessment Approach

In the determination of reliability from assessment and projection analyses, the quality and quantity of data to be used will indicate the level of confidence that can be asserted for this early assessment approach. During the development phase of the program, test data consists primarily of supplier and subcontractor development, qualification and acceptance test phases and S&ID acceptance tests. The number of tests, test time and failure information are primary sources of data available for the preliminary analysis of reliability assessment status. A systematic screening procedure was established with design and reliability engineering concurrence in the determination of the suitability of approved data to be considered for assessment purposes.

Several methods are employed in the assessment of reliability. A nonparametric technique is used to estimate reliability of components, based upon the total number of tests conducted and failures observed, with 50 percent confidence. The exponential distribution is more appropriate when test time and associated failure data are available for assessing reliability. The reliability estimates are conducted on all levels of assembly and are combined with a mathematical model and logic diagram for the system examined. Integrated system reliability of the vehicle is estimated with the system serial rule. A similar approach is used to project reliability for additional ground checkouts that are conducted prior to launch. Projected reliability is an extension of assessed reliability to include the additional tests to be performed prior to launch of a vehicle with the assumption of zero failure criteria.

Predicted reliability may be used as a convenient base, or as an interval of comparison, to determine the relationship between an estimate that was derived from known failure data with mission operating times, and those derived from actual test of the equipment. This appraisal, however, results in an optimistic estimate of reliability. Assessed reliability is a pessimistic evaluation because it is based on limited data from tests of the item. The analytical method does not deal with the interaction or effects of failures upon other systems, and predicted values are used as best estimates when data is not available. Problems that occur are investigated to determine the nature of the failure, the possibility of this occurrence escaping detection during ground checkout, and the corrective action that must take place to ensure nonrecurrence. When major changes or redesign are a result of a problem, and a permanent fix is evident, then data accumulated beyond the change is employed in the calculation of reliability estimates.

The three reliability categories enumerated are considered to be most optimistic for predictions (based upon state-of-the-art information), pessimistic for assessments (based upon available test data), and pessimistic for projections (based upon the assumption of success in all tests scheduled for completion by the launch date). They provide an excellent reference to customer and management to decide "go" or "no go" status at launch.

Control level A is assigned to an item when it has successfully completed in-process testing, source inspection at the supplier's facility, and all S&ID receiving inspection tests. Acceptance means that functional parameters have not drifted beyond the no-go limits designated in any of the test procedures. Control level B provides go status during combined systems operations in the factory prior to static firing. Throughout the manufacturing process, periodic functional measurements are required for most components of the spacecraft. These components and system parameters must remain within no-go limits established by the specification. Control level C is established by the static firing program and the final combined systems test prior to mating operations at the Florida facility. This control level establishes the final go status for spacecraft launch.

TEST FACILITIES

Commercial, supplier, government, and NAA test facilities will be used for Apollo qualification testing. Commercial and government test facilities may be utilized by the suppliers and S&ID when test equipment is not available internally or when test scheduling requires such action.

Commercial, government, and supplier test facilities are approved by S&ID before utilization for the Apollo qualification test program. Each proposed test facility is inspected by S&ID personnel. Laboratory and management personnel are interviewed, and additional information is secured through published material and correspondence. Approval will be contingent upon the appraisal of the following items.

Equipment and facilities
- Environmental simulation equipment (single and combined environmental capabilities)
- Measuring equipment
- Recording equipment
- Calibration equipment
- Standards laboratory
- Failure analysis equipment and facilities
- Photographic equipment
- Plans for new equipment
- Inspection facilities

Methods
- Methods, procedures, and standards documentation
- Housekeeping
- Data recording
- Reporting
- Personnel training
- Vended tests
- Test equipment calibration and certification

Personnel qualification
- Numbers and skills available
- Education
- General experience
- Military specification familiarity
- Statistical test experience
- Failure analysis experience

Management
- Organization
- Supervisory control
- Governmental agency resident representation
- Scheduling

NAA/NASA past experience with facility
- Prior surveys
- Certification record
- Past performance

A listing of test facilities which have been evaluated to determine test capabilities is maintained by S&ID. This list indicates the types of testing which each laboratory is capable of performing adequately. Procurement specifications require that each supplier submit for S&ID approval a list of test facilities which they intend to use. The S&ID test facility listing is the basis for determining their adequacy. S&ID performs a capability survey in cases where no listing is available on a particular test laboratory.

Test facilities being used for qualification will be under continuous surveillance by S&ID representatives during Apollo qualification tests. Previously established standards must be maintained in order to retain approval status.

VIII. NONCONFORMANCE REPORTING SYSTEM

The Apollo requirements for crew safety and for flight success will necessitate planning, management, engineering, and, in many cases, product development that are orders of magnitude greater than those of present technology. To this end, a nonconformance reporting system has been established in all equipment areas, from early design evaluation phase through the complete mission of Apollo. This system will encompass both spaceborne and ground support equipment.

The requirements for the nonconformance reporting system for the Apollo is found in Paragraph 14.3 of NASA Publication NPC-200-2 which states:

> Data reporting, analysis, and corrective action shall involve closed loops providing completed action for all phases of development, fabrication, test, and use of system hardware.

SYSTEM DESCRIPTION

Objectives

The Apollo nonconformance reporting system has as its objectives the recording, collecting and analyzing of data, the ensuring of corrective action, follow-up and feedback on failures or problems occurring at the following locations:

- Major subcontractors
- Vendors and suppliers
- In-plant design evaluation, fabrication, installation, test, and checkout
- Customer-controlled tests and checkout
- Off-site installation test and checkout
- Customer use on the mission

Also, the system provides for the recording, collecting, analyzing, and feedback of all other significant reliability data, such as operating time, cycles, replacement information, maintenance activities, adequacy of checkout equipment, configurations involved, and MRB action.

Requirements

Nonconformance analysis will determine the failure mode, probable cause, and failure effects and differentiate between failures due to inadequate equipment design, and those attributable to human error in fabricating, assembling, handling, transporting, storing, maintaining, and operating equipment. On-the-spot failure diagnoses will be accomplished by a team of engineering specialists, reliability engineers, and quality control engineers; and reasonable facilities will be readily available so that the program can continue without interruption while analysis is being accomplished. The method of analysis and reporting will be compatible with the NASA reporting system. Nonconformance data flow is indicated in Figure 8-1.

Nonconformance and failure data will be fed back and used for corrective action as early as possible in the design phase. The results of analyses will be transmitted to the appropriate design, control, or production activities with priority and provisions for remedial engineering and/or manufacturing actions to prevent nonconformance and/or failure recurrence.

Definitions

1. Failure. The lack of cessation of the ability of an item to meet specified performance requirements

2. Discrepancy. A physical variance of an item that does not conform to drawings, specifications, or workmanship standards

3. Unsatisfactory Condition. Any condition regarded as unsatisfactory from a management, manufacturing, quality control, human factor, reliability, maintainability, design, or system effectiveness point of view that may have an adverse effect on S&ID's products

Report Descriptions

Failure Reporting (Nonconformance Report, NCR)

Nonconformance reporting describes the symptoms at the time of failure, identifies the items involved, describes incidents leading to the failure, and documents the disposition of the hardware. In addition, it describes rework, replacement and analysis required if the nonconforming hardware can be immediately made to conform with the criteria. Figure 8-2 illustrates the NCR form.

Subcontractors and suppliers report failures and conduct analyses on their own forms. These reports are introduced into the NCR system via the same mechanics which process S&ID nonconformance reports.

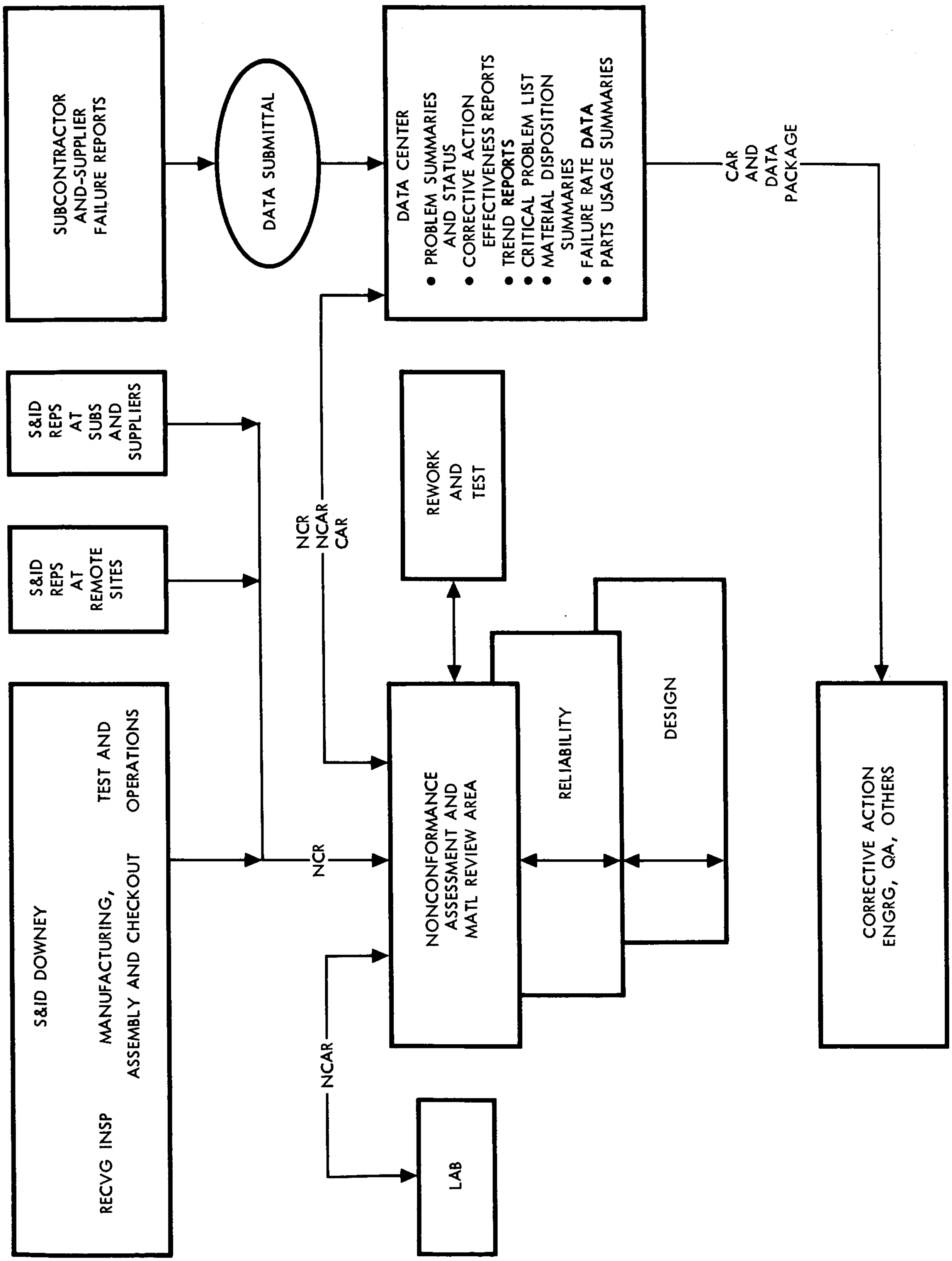

Figure 8-1. Nonconformance Data Flow

Failure Analysis and Corrective Action (Nonconformance Analysis Report, NCAR)

An NCAR form is initiated when an S&ID diagnostic teardown is required to determine the cause of failure. Instructions and the extent of teardown are entered on the form and, subsequently, the result of the teardown analysis. When significant corrective action is necessary, a statement of the action required, those responsible for action and, subsequently, the action taken are entered on the NCAR form. Figure 8-3 illustrates the NCAR form.

Corrective Action Request (CAR, Form 963-M-1)

A 963-M-1 form is initiated by the Nonconformance Assessment area personnel when corrective action assignments are necessary. The 963-M-1 form assigns an area responsible for analyzing the nonconformance, recommending corrective action, and stating the method and implementation of its recommendations. Figure 8-4 illustrates the CAR form.

Supplier Failure Analysis Report (Form 925-R)

A 925-R form is initiated when supplier diagnostic teardown is required to determine the cause of failure of equipment malfunctioning while under S&ID cognizance. A symptomatic description of the malfunction is entered on the form and forwarded to the supplier with the malfunctioned hardware. The results of the teardown analysis, including a description of the failure evidence, cause of failure and corrective action taken are entered by the supplier and returned to S&ID for evaluation and action. Government-furnished equipment (GFE) will be processed using the same procedure through NASA. Figure 8-5 illustrates the 925-R form.

Time Limitations

Nonconformance reports are prepared by Quality Control or Reliability personnel as soon as the problem is encountered. Nonconformance reports issued from S&ID in-plant areas will be transmitted to the data center within 24 hours after the occurrence. Those initiated at remote sites will be received by the data center within 3 days from date of issue. Copies of all failure reports will be maintained by S&ID Data Control Center and will be available to NASA-MSC upon request. Included in these reports will be information required to identify the item, circumstances at the time of occurrence, and symptoms observed.

Rework, replacement, and analysis sections of the nonconformance report (NCR) will be completed and returned to the data center within 10 days of the receipt of the failed article. Where corrective action is required the complete report, containing corrective action taken, will be returned to the data center within 10 days after the failed article is received. These reports will also be available to NASA-MSC upon request.

Diagnostic teardowns of failed articles will be accomplished within 10 days after initiation of the nonconformance analysis report (NCAR). Generally, corrective action implementation will be accomplished within 15 days after initiation of an NCAR requiring corrective action. Corrective action that requires NASA approval and/or negotiations may extend the 15-day requirement. Effectivity dates on the latter will be determined on an individual basis for each such case.

CLOSED-LOOP SYSTEM

A closed-loop failure reporting, analysis, and feedback system will be established for parts, components, and equipments during design, development, test, fabrication, installation, and checkout. GFE and selected items of ground support equipment that must meet assigned reliability requirements will also be included in this reporting system.

Problem and failure reporting and corresponding corrective action for Apollo will be accomplished by using procedures and forms that have been developed. (See Figures 8-2, 8-3, 8-4 and 8-5.) The basic philosophy will be to search out problem areas and solutions and to prevent failures from occurring.

Essential to the failure reporting system are the reliability engineers who are responsible for the analysis of each failure. The reliability engineer is also responsible to follow up each failure to assure that corrective action has been implemented and the problem resolved. Diagnostic teams of specialists will support the reliability engineers in the analysis of problems or specific failures. An urgency category will be established, assuring immediate action on problems affecting personnel or crew safety or accomplishment of mission objectives.

Procedures for the reporting system in use are: S&ID Policy and Procedures J-403 (Nonconformance Reporting), J-403.1 (Failure Analysis of Customer Returned Items), J-403.2 (Supplier Analysis of Components), Apollo Implementing Instruction AII-046 (Apollo Engineering Implementing Instructions Defining Apollo Engineering Responsibilities in Participating in the Nonconformance Reporting System), and Quality Assurance Operating Procedure M1-2.2.1 (Nonconformance Reporting System).

NONCONFORMANCE REPORT

1. REPORT NO.	2. DATE OCCURRED	3. INITIAL NRC NO.	4. PROJECT	5. GEN. ORDER	6. RESON FOR REPORT ☐ FAILURE ☐ DISCREPANCY ☐ UNSATISFACTORY CONDITION	7. SEVERITY ☐ CRITICAL ☐ MAJOR ☐ MINOR

NONCONFORMANCE IDENTIFICATION

8. NC ITEM NAME	8A. NC ITEM P/N	8B. TRAC ☐ YES ☐ NO	8C. NC SERIAL NO.	8D. REF. DESIGN	8E. OPERATIONAL USAGE HOURS CYCLES	8F. QTY UM
9. NEXT ASSY. NAME	9A. N/A PART NO.	9B. TRAC ☐ YES ☐ NO	9C. N/A SERIAL NO.	9D. REF. DESIGN	13. OCCURRED DURING ☐ BENCH TEST ☐ MAINTENANCE ☐ SYSTEM TEST ☐ TRANSPORTATION ☐ COMBINED SYSTEM TEST ☐ STATIC FIRING ☐ ASSEMBLY ☐ COUNTDOWN ☐ FABRICATION ☐ IN-FLIGHT	
10. SYSTEM NAME	10A. SYSTEM P/N	10B. TRAC ☐ YES ☐ NO	10C. SYSTEM SERIAL NO.	10D. REF. DESIGN		
11. E. I. MODEL	11A. E. I. SERIAL NO.		12. GSE/TE MODEL	12A. GSE/TE S/N		

14. OPERATION IN PROGRESS SPEC/PROCEDURE NO: DATE: PARA	15. TEST NO.	16. PRR	17. ASSOC. CONT.	18. WHERE NONCONFORMANCE DISCOVERED A. FAC. B. LOC. C. DEPT.	19. INITIATOR & DEPT.

ASSESSMENT AREA REQUIREMENTS

23. MRB REQ'D ☐ YES ☐ NO	24. NC DISP. ☐ SCRAP ☐ REWORK TO DRW.	25. ASSESSOR	26. DEPT.	27. DATE	28. ANALYSIS/ACTION ASSIGNED TO ☐ ENGINEERING GRP	29. 925 R ☐ YES ☐ NO 30. MRD NO.

20. DESCRIPTION OF NONCONFORMANCE 21. SUSPECTED CAUSE 22. IMMEDIATE FIX	NAME & DEPT.

FORM 963-M REV. 10-63

DATA CENTER

Figure 8-2. Sample Nonconformance Report

1. NCR NO.	NONCONFORMANCE ANALYSIS REPORT					
2. NC ITEM NAME	2A. PART NO.	2B. SERIAL NO.	2C. REF. DESIGN	2D. RETEST TIME	3. PART CONDITION	4. MRB REQ'D ☐ YES ☐ NO

5. HARDWARE ANALYSIS RESULTS 6. DIAGNOSIS (CAUSE)	NAME & DEPT.

PARTS REMOVED AND REPLACED

7. PART NAME	7A. PART NO.	7B. SERIAL NO.	7C. REF. DESIGN	8. PART CONDITION

FORM 963-M-2 REV. 10-63

DATA CENTER

Figure 8-3. Sample Nonconformance Analysis Report

CORRECTIVE ACTION REQUEST

1. CAR NO.	2. REQUESTOR	3. DEPT.	4. DATE	5. DUE DATE	6. DEPT. CAR ASSIGNED	7. ENGINEER RESPONSIBLE

8. HISTORY OF NONCONFORMANCE REPORTS

NCR NO'S							

9. DESCRIPTION OF NONCONFORMANCE(S) (TO BE FILLED OUT BY REQUESTOR) 10. ANALYSIS OF CAUSE (TO BE FILLED OUT BY ASSIGNEE) 11. CORRECTIVE ACTION RECOMMENDED 12. CORRECTIVE ACTION TAKEN (ATTACH CHANGE)

13. CORRECTIVE ACTION APPROVAL

REQUESTOR	RESPONSIBLE ENGINEER	SUPERVISOR, ASSIGNED GROUP	DATE COMPLETED

FORM 963-M-1 REV. 10-63

ORIGINATOR

Figure 8-4. Corrective Action Request

NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

SUPPLIER FAILURE ANALYSIS REPORT

N. A. A. PART NO.		SUPPLIER		DATE OF FAILURE
PART NAME			SERIAL NO.	N. A. A. FAILURE REPORT
SUPPLIER PART NO.	OPERATING TIME	RELIABILITY ANALYST	APPROVED BY	P. R. R. NO.

TROUBLE

TROUBLE EXPERIENCED DURING: CHECKOUT ☐ OPERATIONAL { START ☐ RUN ☐

FUNCTIONING AS UNIT ☐ ASSEMBLY ☐ SYSTEM IN { TEST ☐ MISSILE ☐

TO BE COMPLETED BY SUPPLIER

DESCRIPTION OF FAILURE EVIDENCE FROM TEAR DOWN AND/OR FUNCTIONAL CHECK

ANALYST TITLE DATE

CAUSE OF FAILURE: INCLUDING MODE AND FAILED COMPONENT NAME, NUMBER, SUPPLIER

ANALYST TITLE DATE

CORRECTIVE ACTION BY SUPPLIER INCLUDING EFFECTIVITY DATE OR SERIAL NO.

ENGINEER TITLE DATE

DATE RETURNED TO N. A. A.	COMMENTS ON CORRECTIVE ACTION	RELIABILITY ANALYST	DISPOSITION OF THIS REPORT

FORM 925-R (REV. 9-62)

N. A. A. FILE COPY (Retain until NAA copy is returned)

Figure 8-5. Supplier Failure Analysis Report

Sufficient laboratory facilities are available to perform failure analyses on an urgent, high-priority, regular, and detailed study basis. An analysis facility will be located within reasonable distance from the work area (including field sites), and, if crew safety is compromised by a failure, assistance will be quickly available from any area.

Personnel within the central data processing area will process the reports, and a history retention status and follow-up file will be maintained. Periodic reports will be made to functional management and supervision defining the modes of failure demonstrated by the equipment, frequency of occurrence, corrective action being taken, and an estimate of the measure of effectiveness of the corrective action.

Failures experienced during test and ground operations will be interpreted in terms of influences on mission success or crew safety had they occurred in flight. Best engineering judgment will be employed in evaluating the latter incidents.

The discrete level at which failure can be localized (e.g., material, part, component, subsystem, or system) will be established and the cause of failure identified. Possible failure causes include design, workmanship, human error, procedures or documents, contamination, inadequate maintenance, and wearout.

All symptomatic failures will be analyzed and verified. Those failures that cannot be verified will be given special attention to determine the reasons for the failure symptoms and adequacy of detection and isolation equipment. The failure mode, the effect of the failure, and the priority of the resolutions will be established. The action agency for further study or resolution will be identified and a tentative approach to the solution suggested.

Feedback

Feedback includes the corrective or preventive action accomplished or required, as follows:

- Permanent solution to the problem, including documentation of the implementing instrument
- Temporary fix
- Spares provisioning
- Repair kits
- Revised test procedures or other documents
- Proper training in the use of the equipment
- Other actions as appropriate to the cause of failure

NASA Discrepancy Reports

As outlined in Policies and Procedures J-403, S&ID prepares the customer's discrepancy record (DR) and processes it in accordance with specific contractual commitments.

Discrepancy Reports (DR) are reviewed, summarized and evaluated for Reliability significance.

Monthly Failure Summary

A monthly failure summary, S&ID 62-822, listing failures occurring at S&ID and Subcontractor/Supplier facilities, is regularly submitted to the NASA. The summary identifies hardware by subsystem, and notes a description of the failure, the corresponding failure analysis and its corrective action. Follow-up is made to assure closed loop response on all items reported.

Plans are being formulated for submittal of a weekly magnetic tape in lieu of the monthly failure summary. The tape will include, as a minimum, the same information provided on the monthly summary, with the addition of primary, secondary, suspected, or no-failure designations to describe the classification of failures being reported.

Failure Notification of Explosive Devices

The NASA is notified, within 24 hours of occurrence, of all explosive device failures. A division procedure, J-403, is in effect which directs immediate notification be forwarded by Program Design Engineering.

IX. MANUFACTURING RELIABILITY

Responsibility for maintaining design reliability in the physical product rests with Quality Control and Manufacturing. Failure of equipment in service due to errors in purchasing, packaging, handling, workmanship, and inspection are as important as failures due to design. The Apollo reliability/crew safety requirements necessitate a stringent manufacturing control program. To accomplish this, a quality assurance program integrating Reliability Engineering, Quality Engineering, and Quality Control has been designed to assure that the quality requirements are determined and satisfied throughout all phases of contract performance. The manufacturing reliability program will provide for monitoring, control, and improvement of manufacturing processes and education, motivation and certification of personnel to assure that the reliability requirements are satisfied.

This manufacturing reliability program relies on (1) assessment of design, manufacturing, and inspection capabilities, (2) documented control of procurement, manufacturing, and inspection, (3) reporting and analysis of discrepancies and malfunctions, and (4) a method for recurrence prevention. Cognizance is given to the preparation, utilization, and retention of documents and to the methods for interdepartmental resolution of manufacturing reliability problems.

Assurance of an effective control system is demonstrated in the following manner:

1. Process capability is measured and compared with applicable specifications.

2. Statistical tools are employed to treat failure and discrepancy data to determine actual conditions and predict future reliability trends.

3. Performance and yield charts are established to provide data for corrective action and subsequent measures of effectiveness.

4. Product improvement is accomplished by utilizing design and reliability reviews, expected and actual fraction defective of a product, correlation of discrepancy and failure data, and effective measures to prevent recurrence of a discrepancy or failure.

The detailed organization, methods, and procedures for accomplishing the objectives of the manufacturing reliability program are defined in the Apollo Quality Control Program Plan (SID 62-154).

This document and SID 62-154 are considered as supplemental reports, fulfilling contractual requirements and defining S&ID's total quality and reliability assurance program.

IDENTIFICATION FOR TRACEABILITY

The Apollo identification for traceability system provides the ability to trace the history, application, use, and location of individual items or characteristic lots of items through the systematic assignment, recording, and correlation of controlled serial or lot number identification. The above control is restricted to those items which, if discrepant, would affect adversely the end-product mission success or crew safety. Control is restricted also to those items which are susceptible to failure and which accumulate data useful for analysis. The identification and traceability system provides Reliability Engineering with the timely availability of historical and functional records for use in analysis for failure recurrence prevention and product improvement. Further, the location and disposition of controlled parts is assured in order to provide system purge capabilities. The Apollo identification for traceability system neither replaces nor interferes with other requirements for identification by part number, serial number, or lot number.

Two specifications have been developed which define the criteria for implementation of a traceability system, MA0201-0208 and MA0201-0209, NAA/SID internal and Subcontractor/Supplier specifications respectively.

XIII. ENGINEERING CHANGES

A system has been established to control and measure the influences of engineering changes on reliability. Basically, this system is in conformance with the standard operating procedure for change control and the configuration control requirements of the Apollo program.

Apollo Engineering is responsible for initiating the change control procedure. It will review all changes to determine their classification and process them in accordance with the Standard Operating Procedure. Reliability review and approval of changes are applicable to the following documents:

Engineering drawings
Engineering orders
Process specifications
Material specifications
Test specifications
Procurement documents

All failure data applicable to the specific item being changed are reviewed, as are in-process problem and discrepancy data applicable to the item being changed. Previous design review recommendations are analyzed. Design analysis checklists are used to ensure adequate screening of the change to determine its influence on reliability. Dispositions of the reliability change review are documented. All changes that require NASA approval will incorporate reliability effects and justification data, as presented on the form shown in Figure 13-1.

RELIABILITY ENGINEERING - MCE
MANPOWER AND COST ESTIMATES FOR
DESIGN CHANGES

MCR No. ______
Issue Date ______

ITEM NAME

EFFECTIVITY B/P ______
GSE - S/N ______ AFRM: ______

1. Description of Change (From MCR):

2. Description of Work: (See Note below)

Note: Brief, concise definitive statements of work to be accomplished by Reliability Engineering based on above description of change. Applicable statements as shown on standard task list may be utilized, modified to associate them with the Item Name.

MCR No. ______
Issue Date ______

3. Manhours estimated including offsite trips:

This block will be filled in by Criteria and Evaluation. Please enter your manhours individually required on description of work spread sheets.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		Total
1964														
1965														
1966														
1967														

4. Change in costs (addition or deletion) estimated: ______
Trips/destination: ______
Computers: ______

5. From the Apollo Reliability Program point-of-view, why should this change be supported? (Be clear and concise!)

6. MCR Effectivity is subject to Change Board Adjustment. If this change is essential to mission reliability/crew safety, on which end item of the current Master Development Schedule is it recommended that this change be incorporated, regardless of effect on schedule? Specify and support.

______
Analysis Chief, Date

______
B.H. Hershkowitz, Date
Manager
Apollo Reliability Engineering

Figure 13-1. Sample Reliability Engineering MCE

APPENDIX C

Appendix C has been deleted. (Refer to SID 64-568, "Check List for Design Review Apollo.")

APPENDIX G

REFERENCE DOCUMENTS

NASA DOCUMENTS

NASA Publication on Quality Provisions for Space System Contractors
National Aeronautics and Space Administration, NASA NPC 200-2 (4 April 1962).

Project Apollo, Comments on North American Aviation, Inc., Proposal RFP 9-150. Manned Spacecraft Center, Langley Air Force Base, Virginia (4 December 1961).

Project Apollo Command and Service Module Development Program, The Definitive Contract, NAS9-150, Confidential, NASA Manned Spacecraft Center, Houston 1, Texas (14 August 1963).

MILITARY SPECIFICATIONS

Reliability Program Requirements for Aerospace Systems, Subsystems, and Equipment. United States Air Force, MIL-R-27542 (28 June 1961), Amendment 1 (October 1961).

S&ID PROPOSALS, REPORTS, AND SPECIFICATIONS

Apollo Environmental Design and Test Requirements. NAA S&ID, MC 999-0051 (30 November 1963).

Apollo General Test Plan, Volume I, General Test Plan Summary, Confidential. NAA S&ID, SID 62-109-1 (30 March 1963).

Apollo General Test Plan, Volume 3, Ground Qualification Test Plan, Confidential. NAA S&ID, SID 62-109-3 (30 March 1963).

Apollo General Test Plan, Volume 4, Acceptance Test Plan, Confidential. NAA S&ID, SID 62-109-4 (30 March 1963).

Apollo Qualification Status List. NAA S&ID, SID 62-784.

Apollo Quality Control Program Plan. NAA S&ID, SID 62-154.

Apollo Spacecraft Requirements. NAA S&ID, SID 62-700-2 (15 September 1962).

GSE, Performance and Interface Specification. NAA S&ID, SID 62-57 (15 May 1962).

General Specification, Human Engineering Design Criteria. NAA S&ID, MC 999-0007 (15 September 1962).

Implementation of Instrumental Accuracy Criteria for Apollo. NAA SID 64-25 (17 January 1964).

Identification and Traceability, Internal, Apollo Program, General Specification. NAA/S&ID, MA 0201-0208 (28 June 1963).

Identification and Traceability, Subcontractor and Supplier, Apollo Program, General Specification. NAA S&ID, MA 0201-0209 (8 August 1963).

NASA Project Apollo Spacecraft Business Management Proposal, Vol. II, Parts 1, 2, and 3, Confidential. NAA S&ID, SID 61-281 (6 October 1961).

Reliability Parts Manual, Failure Rate and Application Data. NAA S&ID (November 1962).

Reliability Program Requirement for Apollo Suppliers, General Requirements. NAA S&ID, MC 999-0067 (3 March 1964).

S&ID Apollo Project Subcontractor/Supplier Reliability Program Evaluation. NAA S&ID, SID 64-8 (14 January1964).

S&ID Parts Manual, Vol. 4. NAA S&ID, (December 1963)

Time Significant Item List. NAA S&ID MA0201-0077 (25 May 1964)

AUTONETICS REPORTS

Description and Comparison of Computer Methods of Circuit Analysis. NAA Autonetics Division, EM 6839 (30 June 1961).

Description of the Data Processing Problem for Minuteman High Reliability Electronic Parts. NAA Autonetics Division, EM 2493 (15 November 1961).

APPENDIX H

APPLICABLE DOCUMENT REQUIREMENTS AND DEVIATIONS

This appendix lists the existing S&ID documents that implement the requirements of specifications MIL-R-27542 (USAF) and NPC 200-2. Under the comments column heading are S&ID's objections deviations. The paragraph numbers and statements in the requirements column are those of MIL-R-27542 (USAF) and NPC 200-2.